Tuning the Torch for Lead Isotopes: The Battle in Lugdunum

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To celebrate Francis Albarède's pioneering work in developing high-precision, high-throughput Pb isotope analysis by Tl doping and sample-standard bracketing MC-ICP-MS [1], I here review some selected contributions by the Lyon group to cosmochemistry, geochronology, Mars, mantle geochemistry, and archeometry using this technique. The superior precision of MC-ICP-MS compared to unspiked Pb TIMS work led us to revisit several classic but crucial questions involving Pb isotopes. We determined the age of the Solar System from Pb-Pb measurements of refractory inclusions in meteorites [2], a result only now confirmed by independent means despite tumultuous revisions of U isotope compositions and major improvements in analytical precision and blanks since our early work. We further re-determined the initial Pb isotope composition of the Solar System and the solar nebula Th/U [3] and found Pb isotope evidence that some asteroids accreted and differentiated within only one million year of the formation of the Solar System [4], thereby placing constraints on nebular evolution. Our Pb-Pb ages of SNCs [5], the shergottites in particular, are important because they finally bring the ages of Martian meteorites (4.1 Ga) into agreement with cratering chronology and satellite observations for Mars, as well as with extinct radioactivities, but are controversial because ages inferred from other chronometers are far younger (160 Ma). The high throughput of MC-ICP-MS further changed the geochemical approach to understanding mantle heterogeneities in volcanic time series, such as in Hawaii [6], and the exploring of length and time scales of isotopic heterogeneities along the world's mid-ocean ridges and, hence, the deep Earth, allowing for full-fledged spectra amenable to physical and statistical modeling to be obtained [7, 8]. A spectacular new result is the evidence of Pb-Hf isotopic 'toggles' along the SEIR, and their random distribution, indicating that the local mantle has lost all memory of its mixing history [9]. Another key result was the Pb-Hf correlation in Hawaiian lavas showing that entrainment of the upper mantle by plumes is minimal [10]. We currently apply Pb isotopes to tracking Pb ore provenance in ancient Rome in order to shed new light on the heavy metal record of local economic activity, urban development, and warfare.

[1] White *et al*. (2000) [2] Bouvier *et al*. (2007) [3] Blichert-Toft *et al*. (2010a) [4] Blichert-Toft *et al*. (2010b) [5] Bouvier *et al*. (2009) [6] Blichert-Toft & Albarède (2009) [7] Agranier *et al*. (2005) [8] Meyzen *et al*. (2007) [9] Hanan *et al*. (submitted) [10] Blichert-Toft *et al*. (1999).

Impact of long-term nitrogen deposition on the fate of nitrogen in peatlands

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Large areas of northern peatlands in Europe and North America have been affected by elevated long-term nitrogen deposition at levels of 0.5 – 2 g N m^{-2} yr^{-1}, and in extreme cases upt to 5 g N m^{-2} yr^{-1}. The consequences of this deposition for the fate of nitrogen, especially the allocation of the element between vegetation and peat and the mobility in dissolved form, and for the carbon cycle are only poorly known to date. We investigated this issue using ecosystem modelling based on a long-term fertilized site and experimentally with mesocosms from five different European peatlands that have been exposed to range of 0.2 to 5 g N m^{-2} yr^{-1}. The mesocosms were placed in a greenhouse under controlled light and water table conditions for a period of 160 days after an initial equilibration period. We added a $^{15}N\text{-}NO_3$ tracer with irrigation water to determine how the allocation of nitrogen in these peatlands differed and also investigated the carbon exchange and productivity of the sites under these conditions. The results show that the Sphagnum moss layer was not severly impaired at any site and that even under severely N polluted conditions nitrogen was still taken up by the moss layer. The effectivity of the moss filter for the element declined, however, and some breakthrough occurred, whereas nitrogen in the pristine sites seemed to be indirectly transferred into peat by the root system of vascular plants. Overall more nitrogen was taken up by vascular plants in the more polluted sites. Elevated nitrogen deposition lead to raised ammonium and DON concentrations even at lower deposition levels but strongly elevated nitrate concentrations only occurred at the most polluted site. Substantial differences in carbon cycling between sites did not occur in the mesocosm experiments. The ecosystem modelling exercise using the new model PEATBOG showed that the most important impacts of nitrogen deposition are to be expected are through indirect changes in the ecosystem structure, which was altered from moss to shub and then grass dominated in the simulated system. The replacement of plant functional types lead to a higher rate of nitrogen processing in the system and higher productivity and carbon uptake. Also in the simulations the peatland remained a sink of nitrogen with only moderately raised nitrogen export.

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